From Proceedings of the 24th Meeting of the International Congress on Occupational Health Nice France, September, 1993.

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Assessing Occupational Exposures in Epidemiology Studies

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Introduction

A dose-response trend is a primary criterion for establishing causal associations (Monson). In the occupational setting, dose has usually been approximated by exposure, because air concentrations have more often been measured historically than biologic concentrations. In many cases, however, even airborne exposure measurements are not available, and surrogate measures of exposure, such as ever/never employed, duration of employment and semi-quantitative estimates, have been used. Limitations of these approaches have been described elsewhere (Stewart and Herrick).

Despite their crudeness, these approaches have been successful in finding occupational associations and establishing causality. Why, then, are we seeing more interest in the development of quantitative estimates ? First, there is an increased emphasis today, both in the private sector and in regulatory agencies, on risk assessment for evaluating health effects, and the traditional approaches do not allow quantitative estimates of risk. Second, the likelihood of finding large risks, which may be observed even when severe misclassification occurs, has diminished (Wegman). Investigation of diseases with lower risks is less tolerant of error and demands more accurate estimates of exposure. Third, there is growing recognition that mechanisms of toxicologic action may be complex, and simply accumulating exposure may be insufficient. Exploration of different exposure measures may be crucial in identifying associations, and the absence of quantitative estimates makes such an exploration more difficult. Finally, the growing number of measurements available since the 1970's (at least in the U.S.) makes such assessments possible.

As a result of these changes, more interest and emphasis is being placed on the development of quantitative exposure estimates. At this time, however, there are not established, standard methods to develop such estimates, nor are there recognized criteria for the use of the different methods. This is likely to be due, in part, to the newness of the field, but it may also be due to differences in the availability of exposure information in various studies.

Today, I'll be describing the process of assessing historical exposures in epidemiologic studies of chronic occupational diseases in both the cohort and the population-based case-control designs. These two study designs for chronic diseases are the focus of this presentation because these studies often lack or have limited historical measurements with which to estimate exposures. Cross-sectional studies will not be discussed here because direct measurements are generally possible.

The format of this paper is to describe, for each of the two study designs, collection of data, guidelines for documentation, and methods used to assess exposures and their limitations. A brief discussion on evaluating the validity and reliability of the methods will then be given, along with recommendations for improvement.

Cohort Studies

Data Collection

One strength of the cohort design over the case-control design is that for most studies, the focus is only on a few workplaces. Visits to the facilities can, therefore, generally be made to collect work histories and process and job description changes. Records that may be useful when evaluating exposures have been described by others (Checkoway et al., 1987, Checkoway et al., 1989) and can be found in Table I (Stewart et al., 1991a). In addition, it is possible to conduct interviews of long-term workers and collect additional monitoring measurements.

Table I : **Types of Exposures Records**

Work histories
Biologic monitoring results
Air monitoring results
Job descriptions
Standard operating procedures
Plant layouts
Process flow charts, operation descriptions
Purchasing records, shipping records, production records
Engineering reports
Accident reports and other records on non routine occurrences
Quality control reports
Records on shutdowns, strikes, layoffs
Organizational charts
Photographs
Industrial hygiene programs
Medical records
Worker compensation records
Published literature
Suppliers' records

Documentation of Exposure Data and Assumptions

These various types of exposure records and the information they contain can quickly become unmanageable unless systems are developed for easy storage and retrieval. At the National Cancer Institute, we believe that studies should explicitly identify what information was used in the evaluation of exposures because : it forces the industrial hygienist to think carefully about the job being evaluated, it facilitates identification of vague or ambiguous jobs or exposure characteristics that indicate where more information is needed and it allows for easy review by others of the decisions made.

Table II : **Exposure Characteristics Described in Job Exposure Profiles**

Process description
Physical location of the job
Tasks and duties
Significant changes that occurred in the process
Unusual occurrences
Production rates
Frequency of exposure
Frequency of peak exposures
Reported health effects
Frequency of dermal exposure
Use of personal protective equipment
Level of physical activity
Presence of other chemicals

In an on-going cohort study of acrylonitrile workers in eight companies, we have developed a user-friendly, computerized system that organizes exposure data, allows for easy data entry and retrieval and provides documentation of assumptions made during the exposure assessment process. We call this system Job Exposure Profiles (JEPs) (Stewart et al., 1992b). For each exposed job, the industrial hygienist describes the environment and the job characteristics in a JEP, based on industrial hygiene exposure assessment principles. Table II identifies these characteristics. We describe each of these characteristics and indicate whether the information was collected from a record, such as shown in Table I, or an interview with a worker, and where it can be found in the study documents. If the information was not obtained from either of these sources, but rather the entry was based on an assumption, the reasoning upon which that assumption was based is described in a comment section.

The Job Exposure Profiles system provides, therefore, a mechanism for complete documentation of the knowledge held by and the assumptions made by the industrial hygienist performing the exposure assessment. It also provides guidance to the investigator as to what information should be collected for epidemiologic studies. The system can be used in other studies and we plan to make it available to others in the near future. For those investigators who do not have access to a personal computer, paper copies of the Job Exposure Profiles can also be used to document the exposure environments of jobs.

Exposure Assessment

After collecting and organizing the data and documenting the exposure characteristics, the next step of exposure assessment is to evaluate the data to determine how to assess exposures. Generally, the method selected depends on the availability of industrial hygiene monitoring data.

In the last twenty years, two types of estimation methods have emerged: methods based exclusively on monitoring data (which are possible when measurements are available for most of the jobs and of the changes that occurred in the plant) and methods used when the number of monitoring results is small relative to the number of jobs and changes. This latter method requires making assumptions and performing extrapolations.

Measurement-based Methods

Means

When sufficient air monitoring data are available, means have generally been used as estimates of exposure. This is an attractive approach that requires few assumptions. It does, however, require enough monitoring results across jobs and over the study period to complete all or most of the job/year cells. It works best when few changes in exposure levels have occurred over time. For example, Smith et al. conducted personal sampling for a number of chemical exposures in a study of workers in a silicon carbide operation (Smith et al., 1984). Because few changes had occurred over the study period, the monitoring results were sufficient to be representative of historical exposures.

In most workplaces, however, exposure levels have not been constant over time because of changes in the process, job tasks or engineering controls. Measurement data are not often available for periods prior to all of the changes that took place in the workplace, particularly in early years. When data are available in early years, they are often area results of short sampling duration, which may not be representative of full-shift personal exposures. For example, in another study by Smith et al. of smelter workers, only area measurements were available prior to 1974, but there was an overlap of these samples with personal measurements for one year (Smith et al., 1978). The authors compared the area and personal measurements and found that the area samples were generally higher than the personal samples. The authors of an aluminium smelter study also found differences between the two types of measurements, but resolved it by using the differences between the area and personal samples during the years of overlap to estimate earlier exposures (Armstrong et al.)

Statistical Approaches

Statistical models based on available monitoring data can be used to predict exposure levels if enough measurements exist across the jobs and over the years of the study to complete the missing data cells. This approach has the advantage of being straightforward and it should be fairly reproducible.

Several statistical techniques have been used (Eisen et al., Greife et al., Woskie et al., Dement et al., Yu et al.). Two problems may arise, however, in using statistical approaches. First, these treatments need a small number of jobs relative to the number of jobs monitored, but there may be several hundred jobs in a plant. A study of granite shed workers only had 32 jobs titles, and they could be grouped into 25 job categories for analysis of variance (Eisen et al.). In a workplace with several hundreds to thousands of job titles, however, it is likely that most jobs will not have been monitored. Reduction of a large number of jobs to a small enough number for use in a statistical model may result in job categories with heterogeneous exposures. The heterogeneity of exposures within a job title has received recent attention (Rappaport), but the impact of this phenomenon on epidemiologic studies is not yet known. A second problem is that when monitoring data are not available prior to changes that occurred in the workplace, it is not possible to model exposure levels for the years preceding those changes. Unfortunately, this is a situation often encountered by investigators.

Calculation of Means Using Tasks and Time

Many historical data are area measurements and/or of short duration. The use of these data as full-shift personal samples is problematic, as noted in the smelter study described above (Smith et al., 1978). To use short-term or area samples to develop estimates that are more representative of full-shift exposures, some investigators have weighed short-term monitoring results by time (Dement et al., Rice et al.). For example, in a study of asbestos workers the authors used area measurements to calculate zone averages (Dement et al.). Eight-hour time-weighted average (TWA) exposures were then calculated by summing the products of each zone's average exposure and the time spent in that zone and adding task exposures where appropriate. This type of approach requires that the monitoring results be available for most tasks or areas in the study and that time spent in the zone or task can be estimated.

Grouping of Similar Jobs

In a North Carolina study of dusty trade workers, all facilities within a commodity were considered to be similar enough to combine all measurements across those facilities (Rice et al.). Other investigators have also grouped jobs (Greife et al., Seixas et al.) or facilities (Dodgson et al., Lemasters et al.) to obtain a mean for a broader occupational group or for an industry category when monitoring data were unavailable for a number of the jobs or companies being evaluated. Grouping of jobs or industries requires a careful evaluation to ensure that exposures are similar within the occupational group or industry. If exposures are not similar, combining jobs with heterogeneous exposures could result in subjects being assigned to the wrong exposure level (Rappaport). A similar problem could arise when grouping jobs across facilities.

The assumption of homogeneity of exposure was made in a study of coal miners (Seixas et al.). Four occupational groups were created. Where monitoring data were available for an occupational group in a specific mine for a specific year, an arithmetic mean was calculated. Where these three-way cells (occupational group/mine/year) could not be calculated due to a lack of data, a hierarchy was used to calculate exposures for: occupational group/year cells ignoring mine, mine/year cells ignoring occupation and finally, year cells ignoring both mine and occupation.

In study of workers in styrene-product facilities, the homogeneity of exposures was statistically evaluated (Lemasters et al.). An analysis of variance found that little variation could be attributed to job titles after accounting for the type of product, the type of process and the type of exposure (direct or indirect) (Lemasters et al.). To derive the exposure estimates, all the monitoring results within a company on each day were combined to form a mean. These daily means were used to calculate a mean for a company. The means of each company were then used to calculate the exposure mean for each type of process, product and exposure.

Prediction from Other Cells

Some investigators have used means of monitoring results for some jobs to predict exposure levels for other jobs. When the same adjustment factor is applied consistently across all jobs, reproducibility of the estimates increases. Careful examination of the workplace and jobs characteristics must be made, however, to ensure that there is nothing to suggest that the same treatment across all jobs is inappropriate.

In a study of granite workers employed in 49 sheds, investigators developed a matrix of job and shed concentrations (Theriault et al.). Arithmetic means of measurements taken by the authors were used to fill in the various job/shed cells of the matrix. There were several cells, however, that were empty. For these cells, for cells that had a mean concentration greater than two standard deviations from the average of all the jobs in that shed or for cells that had a mean concentration greater than two standard deviations from the average of that job across all sheds, the completed cells were used to predict levels. The value used to fill the missing data cell was calculated by multiplying the mean of the jobs across all sheds, by the mean of the sheds across all jobs and dividing by the average mean for all jobs and sheds.

Exposures have also been estimated using monitoring results on a different chemical than the one of interest. This approach was used in an aluminum smelter that had benzene soluble materials (BSM) measurements over the study period and benzo(a)pyrene (BaP) measurements after 1976 (Armstrong et al.). The authors derived a ratio using BaP and BSM measurements from 1976 to 1983 for 19 occupational groups. Assuming the ratio remained the same over time, they applied this ratio to determine pre-1976 BaP levels.

Methods without Sufficient Monitoring Data

All of the methods just described require sufficient monitoring results relative to the number of cells needing estimates. In contrast, when monitoring results have not been sufficient, a less rigorous assessment method has often been used by investigators. An example of such an approach is a study of formaldehyde workers (Stewart et al., 1986). Where monitoring results were available, they were used to develop exposure estimates. Where monitoring data did not exist, the authors evaluated the tasks being performed by the jobs and estimated the exposures from similar jobs. No formal rules for evaluating similar jobs were followed, however, which probably resulted in estimates of low reproducibility.

In our on-going study of acrylonitrile workers, we again were not able to rely exclusively on monitoring data, due to the insufficient number of measurements on many of the 3500 jobs in the study. Being dissatisfied with the approach taken in the formaldehyde study (Stewart et al.,1986), however, my collaborators at NIOSH and I have taken a more rigorous approach to documenting and assessing exposures in this study.

In addition to the Job Exposure Profiles described earlier, we have developed formal methods to develop exposure estimates. Several estimation methods were developed because of the variability in the exposure data across jobs and through time. The methods include calculation of means based on personal monitoring results, using a ratio method where the ratio of exposures of some jobs are applied to other jobs, calculation of exposure means for homogeneous exposure groups using the measurements of all the jobs within the group, and use of area measurements weighted by time. Formal criteria for using these methods were developed, as was a hierarchy of their use, based on their ability to predict the measurements. Each of the estimates was documented as to how it was derived and the assumptions made, which allowed reviewers to easily follow the decision-making process.

Estimates of Exposure Over Time

The methods described above, whether based on statistical principles or professional judgment, are used to develop an estimate for at least one cell for each job. This provides a referent cell for completing the remaining cells through time. To develop estimates for these cells, the same approaches just described have been used, as well as a few others. First, some investigators have assumed that no changes took place in the workplace (Smith et al., 1984, Roach, Eisen et al.). Others have interpolated estimates from means of other years (Roach) or have assigned an arbitrary value in a particular year, based on information from other studies (Theriault et al.).

Some investigators have reduced the number of measurements necessary by developing time periods. Investigators may use time periods rather than years when evidence indicates that no changes in exposure levels occurred within the time period. The method for determining time periods has varied. For example, in the North Carolina dusty trades study, the silica monitoring results for each company were plotted by time and sample location (Rice et al.). Any point in time when all measurements were above or below all successive measurements was considered as evidence of a change in the workplace environment. Mean concentrations were then calculated for before and after the change. If the plot of measurements showed no such pattern, the mean concentrations from all the years were averaged.

Other investigators have developed time periods based on changes in the workplace identified from interviews of workers or from engineering and other production reports. For example, multiple regression models have used workplace changes as independent variables (Dement et al., Greife et al.) if they achieved a particular level of statistical significance. Information on such changes has also been used with professional judgment to derive exposure levels (Armstrong et al., Stewart et al., 1986, Dodgson et al.). In the study of formaldehyde workers, for example, an estimate of the exposure was made after identifying the changes that had occurred in the workplace. The reproducibility of estimates based on this approach, however, is likely to be low, because there were no formal criteria followed in developing these effects.

A study of manmade mineral fibers used a similar approach, but the estimates of the workplace changes were explicitly described (Dodgson et al.). The effects of two of the most important changes were evaluated using an experimental design. Other less important factors were identified with estimated multipliers. The appropriate multiplier for each factor was then applied to each of the measurement means to derive the exposure estimates. This study is an improvement over the study of formaldehyde workers (Stewart et al. 1986), in that the weights of the exposure modifiers were defined.

Evaluation of Validity and Reliability

Regardless of the method used, the validity and reliability of the estimates developed should be assessed wherever possible. Methods are valid if the estimated exposures are the same as the true exposure experienced by the study subject. Reliable procedures yield the same exposure decision when applied to the same reported occupation on repeated independent assessments, whether by the same industrial hygienist or by different industrial hygienists.

Obtaining valid and reliable quantitative exposure estimates is important when sufficient industrial hygiene monitoring data are not available. Without valid and reliable exposure estimates, the likelihood of finding true associations, the credibility of the findings and the comparability of results across studies diminish. Few method evaluations have been conducted in epidemiologic studies because of the lack of data. The validity and reliability of estimates should improve, however, with both careful review of the data and with documentation of the exposure environment and characteristics as, for example, in a system such as the JEPs. Efforts to evaluate the validity and reliability of the estimates can, however, often be made.

Some investigators have used biological monitoring results, either historical or current, to validate estimates (Kipen et al., Hertzman et al., Teschke et al). Others have either used a subset of the air monitoring data as the gold standard (Greife et al.), or they have used as the gold standard measurements generated after simulating the study exposure conditions (Cherrie et al.).

Recommendations

Currently, there is not enough information available to determine which estimation method works best under which circumstances. As more validation and reliability studies are conducted, such criteria may be developed. Until 15
that time, considerations in the selection of a method should include : l) the number of job titles needing evaluation, 2) the appropriateness of grouping job titles into fewer job groups, in light of the heterogeneity of the exposure(s) of interest and other exposures, 3) the number and type of monitoring results per job/job group over the years of the study and 4) the availability of monitoring results relative to the changes in the workplace due to process, engineering controls, and work practice changes.

Case-control Studies

Case-control studies are useful because they can investigate rare diseases and they generally cover small workplaces, but the difficulties in assessing historical exposures in case-control studies are even greater than in cohort studies because less exposure information is available and because of the large number of workplaces involved. Nonetheless, my colleagues at the National Cancer Institute and I believe that improvements can be made in assessing exposures.

Data Collection

The typical approach to collecting exposure information is to interview the study subject or a next-of-kin for the jobs, employers and dates held by the subject. Qualitative analyses of having held a job or having the potential for an exposure inferred from a job (from job exposure matrices, e.g., Hoar et al.) and semi-quantitative estimates of the probability of exposure (definite, probable, possible) or the level of exposure (low, medium or high) have been the traditional methods of exposure assessment. Such approaches are likely to have significant misclassification because they assume that everyone holding a particular job has the same exposure at the same level and they ignore the variability of exposures that is found within jobs or workplaces.

A major advance in assessing exposures in case-control studies has been described by Siemiatycki and Gerin (Gerin et al., 1985). These investigators recognized that exposures are often idiosyncratic to the person holding the job, i.e., that everyone with the same job title does not necessarily have the same exposure. Siemiatycki and Gerin therefore used information on activities, equipment and materials used, and responses to occupation-specific questions for each individual study subject when assessing the exposures of each individual (Gerin et al., 1985). Although this method appears to substantially increase the accuracy of the assessment (Dewar et al., 1991), it has not gained the recognition it deserves, in part, we believe, due to the perceived practical feasibility of the method.

We have recently modified their approach in an on-going brain and stomach cancer study. In this study, the typical occupational history (job title, type of business, activities, etc.) is collected by telephone interview. This information is keyed onto a form and reviewed by an industrial hygienist who can enter three questions per job, querying the nature of the job and/or exposure environment. Typically, these questions have asked the duration or frequency of exposure or of performing a task, and the level of sensory perception (e.g., dust or vapors as strong/heavy, moderate, light). We call this form SCORE, a Self-Corrected Occupational REport (Stewart and Stewart, 1993b). The form is mailed to the interview respondent for corrections to the work history and for completion of the questions. Approximately 70% of the 153 respondents, so far, have returned the forms and of these, 70% responded to the questions. We performed a preliminary analysis to determine if the information received changed the exposure evaluation made by the industrial hygienist. Assessing exposures for general categories of dust, solvents and polycyclic aromatic hydrocarbons, we found that between 30 and 50% of the assessments changed after receipt of the new information.

In this study, the supplemental questions are sent to the respondent after the telephone interview has been completed. Since this study, we have initiated a new study that has further modifications. In this second study, we have developed sets of standard questions for various jobs we expect to see with higher frequency (as done by Gerin and Siemiatycki) (Gerin et al.).

These questions will be administered as part of a computerized assisted interview. When the interviewer enters a job title into the computer during the interview, the appropriate set of supplemental questions will appear on the computer screen for the interviewer's use. Having the questions computerized will allow easy and fast retrieval of detailed industrial hygiene questions by an interviewer who is not familiar with industrial hygiene principles.

Documentation and Exposure Assessment

Traditionally, exposure levels in case-control studies have been assessed by assigning an ordinal exposure score, e.g., none, low, medium and high, without a quantitative definition of the boundaries of each category. The literature that was reviewed by the industrial hygienist when developing the estimates has often been described, but no investigator, to my knowledge, has described in detail how estimates of exposure have been derived. There is obvious misclassification in using ordinal categories because all jobs are assigned to only four exposure categories, and there could be substantial differences in exposure levels within a category. Scores are open to variable interpretation and they reduce the usefulness of study findings for public health purposes (e.g., regulation or preventive measures in the workplace). Ordinal categories with well specified boundaries have been developed (Partanen et al., 1991), but I am unaware of any study that has developed actual estimates of exposure.

Recommendations

More efforts should be taken to collect person-specific exposure information in case-control studies. There are, in addition, other procedures that can improve exposure assessment in case-control studies. Reports of occupational histories may be prone to error, particularly when reported by next-of-kin (Lerchen and Samet, 1986; Coggon et al., 1985). Evaluating the quality of the reported information may help to identify occupational histories that are likely to contain errors, and by coding them as such, they can be removed from the analysis if desired.

If the reported information appears to be inconsistent or vague, the respondent could be recontacted by using the SCORE report. Another strategy could be to contact co-workers. We have used such an approach in an on-going case-control study of leukemia and brain cancer among embalmers (Stewart et al., 1992a). In this study, attempts were made to contact co-workers of 277 subjects. For 95% of the subjects, at least one co-worker was interviewed, and of these, about 70% had worked with the subject before 1970. A third option would be to contact the employer of the subject, although the feasibility of this option has not been assessed (Stewart and Correa, 1991).

The more first-hand knowledge the industrial hygienist has about the job and industry, the more likely it is that the assessment will be accurate. If the industrial hygienist does not have direct experience with the job/industry, the best strategy would be to contact the particular employer of the subject (Stewart and Stewart, 1993b) or consult with several industrial hygienists familiar with the industry (Miligi and Masala, 1991).

Other factors contribute to uncertainty when making an exposure decision. Use of most chemicals varies even within a single industry, and so few chemicals are found at every worksite within the same industry. The probability that a job is exposed varies with the process and its environmental characteristics, the chemical being assessed, and the tasks being performed in the job. Asking direct questions of the respondent, either in the initial interview or on the SCORE form, may allow a definitive evaluation of the probability exposure. If information still is not specific enough, the best estimate of the probability that exposure occurred may be based on the frequency of exposure in the population of workers holding the job in that industry. Such an estimate could be derived after reviewing existing data bases, such as the Occupational Safety and Health Administration's Integrated Management Information System (Stewart and Rice), the Environmental Protection Agency's TRI system (U.S. Environmental Protection Agency, 1991) or the National Institute for Occupational Safety and Health's Job Exposure Matrix (Sieber et al.). These data sources offer an objective basis for quantitatively estimating exposure probability.

Table III : Determinants Crucial to Assessing Exposures

Determinant	Characteristics
The chemical	Physical State Volatility Route of exposure
The source	Type of equipment Production variables (quantity of the substance being used or produced, temperature, pressure, etc.) Mechanism of release
Transport of the chemical	Engineering controls Type of environment (indoors, outdoors)
Job/individual	Frequency, duration of exposure Distance from the source Individual work practices Use of personal protective equipment
Facility	Number of employees Presence of an union Physical layout

Estimating quantitative exposure levels in these studies is an enormous challenge for the industrial hygienist but should be attempted. As described earlier, there are no standard methods to estimate exposures even in cohort studies and methods for the case-control design is even less developed. In addition, due to the complexity of the workplaces, it is unrealistic to evaluate all determinants affecting exposures.

We have identified five determinants from basic industrial hygiene principles as being central to exposure assessment (Table III). Identifying the major determinants that influence exposure and identifying criteria for assessing those determinants will make it more likely that accurate estimates are developed. Also, by documenting what exposure information is known and what assumptions are made with regards to these determinants, the consistency of the estimates across jobs is likely to increase because the same determinants are considered for each job. Finally, estimates of multiple assessors either in the same study or in different studies are likely to be more consistent when using the same criteria, thus decreasing differences in results across studies.

Even having evaluated these determinants, however, the industrial hygienist still faces a considerable challenge in translating these determinants into an exposure level and in being consistent in assigning exposure levels across jobs. To facilitate the interpretation of the exposure determinants into quantitative estimates, benchmarks of already evaluated jobs may be helpful (Gerin et al., 1985). If these jobs are ones on which many measurements have been reported in the literature, they and their mean exposures could serve as points of reference for developing quantitative estimates. In addition, to increase consistency in estimating exposure levels from job to job, a cumulative list of the reference jobs and the jobs evaluated in the study could be retained by exposure level.

Evaluation of Validity and Reliability

As in cohort studies, evaluation of the validity and reliability of the exposure estimates is important to the credibility of the study. The most direct and practical measure of reliability is to examine intra- and interrater reliability, and there have been a few studies that have evaluated reliability of assessments (Goldberg et al., Hayes et al.). Evaluating validity is much more difficult in case-control studies than in cohort studies, due to the large number of workplaces, which makes it difficult to collect monitoring data. It may be possible, however, to conduct air monitoring in a few facilities and compare the results to estimates derived from those same employees.

Table IV : **Effect of improving Exposure Assessment on Odds Ratios**

(1)		prevalence = 0.8			prevalence = 0.1		
	true OR =	**1.0**	**1.5**	**2.0**	**1.0**	**1.5**	**2.0**
60		1.0	1.14	1.30	1.0	1.07	1.14
70		1.0	1.19	1.39	1.0	1.11	1.15
80		1.0	1.27	1.56	1.0	1.15	1.26
90		1.0	1.36	1.74	1.0	1.26	1.38

(1)		prevalence = 0.8			prevalence = 0.1		
	true OR =	**1.0**	**2.0**	**4.0**	**1.0**	**2.0**	**4.0**
60		1.0	1.26	1.68	1.0	1.11	1.24
70		1.0	1.30	1.90	1.0	1.18	1.26
80		1.0	1.46	2.41	1.0	1.24	1.53
90		1.0	1.66	2.99	1.0	1.44	1.78

(1) : % correctly classified

Effect of Improving Exposure Assessment

The procedures described above should improve exposure assessment. Such as improvement, even if small, can have a large impact on disease risks, depending on a number of factors. To determine the effect of improving estimates, odds ratios were calculated in a hypothetical study to determine what would be seen under varying degrees of misclassification, prevalences of exposure and risk (Table IV). This table shows that the odds ratios do increase with each increase in accuracy of the exposure classification, some only slightly, others more substantially.

Conclusions

This paper has described approaches used to estimate historical levels of occupational exposures in both cohort and case-control studies. The cohort study usually has more exposure information and therefore a variety of estimation approaches have been used, but criteria when to use these methods need to be developed. Although exposure assessment in case-control studies is more difficult, a more rigorous approach to estimating exposures has been suggested. For both types of studies, documentation should be made of the information known and the assumptions made. The criteria used to evaluate exposures and develop quantitative estimates should also be explicitly defined in the study report. In addition, assessment methods should by evaluated for validity and reliability wherever possible.

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